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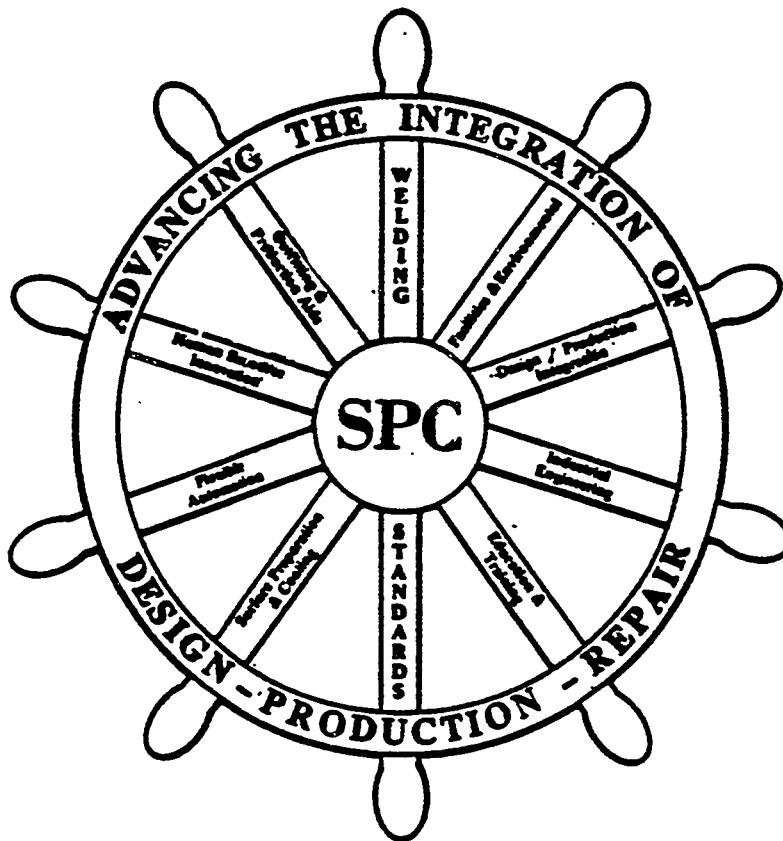
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IHI Zone Logic Application to Electrical Outfitting on Highly Sophisticated Ships

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ABSTRACT

Outfitting electrical cable in highly sophisticated ships, such as, research vessels, patrol boats, etc., has significant impact on every aspect of ship construction, modernization, overhaul and repair. In other words, cost, schedule adherence and quality for very sophisticated ships are fully dependent on the performance of electrical work. Ishikawajima-Harima Heavy Industries, Co., Ltd. (IHI) has been exploiting zone logic, also recognized as technology, for construction of virtually all ship types. But, the extensive cable footage in sophisticated ships requires special considerations and techniques. This paper presents practical design and production processes for zone outfitting electric cable.

Special focus is on:

- 1) functional end detail design,
- 2) conversion of system-oriented design data to zone-oriented work packages called pallets, and
- 3) work methods currently employed in IHI shipyards.

INTRODUCTION

significant advances are being made in North American shipyards to reduce cost and to assure schedule adherence by applying zone logic, for construction, and also for modernization, overhaul and repair of ships. Everyone so involved acknowledges that much more needs to be done. But, most do not yet understand how to include electric-cable work within the zone approach for integrated hull construction, outfitting and painting.

Traditionalists regard electric-cable work as incompatible with zone logic. They insist that most cables must be installed on board because, "cables extend over several ship compartments and/or zones." Where traditionalism has prevailed, cable work has taken a back seat while full-scale explications of zone logic are achieving unprecedented productivity increases for other types of work. Two different build strategies are underway at the same time. Unavoidably, cable installations then proceed rather haphazardly under

old-fashion control which relies on each supervisor's experience and intuition while other work proceeds in a much safer and productive manner. Moreover, system-oriented work does not yield the corporate experience needed for constant analysis and constant improvement in design details and work methods.

Also, continuing the system-by-system approach for installing electric cables while hull construction, other outfitting and painting are zone oriented, increases the probability of unsafe work situations, cable damage, and rework even for the other types of work. Any combination of these conditions could lead to a deterioration in quality and catastrophic confusion in attempting to implement a work schedule for a ship as a whole.

Obviously, the solution lies in integrating the installation of cables with other types of work. In this connection, design data which are originally generated in a system-oriented manner must be rearranged in accordance with zone-oriented classification criteria. Cables have to be grouped for both material and production control in accordance with problems inherent in their installation. Thus, group technology (GT) has an important role in the advanced techniques for installing cable.

The exploitation of GT for cable work is firmly established in IHI and is now regarded as indispensable, particularly for the most sophisticated ships. This advanced process has brought about a remarkable outcome for every aspect of electrical outfitting. An electric-cable length is regarded as a fitting every bit the equivalent of a single pipe piece. The approach has made it possible to adopt the "Cable Pre-cut Method" which is essential for making cable-installation work safer, more productive, and susceptible to production control commensurate with other outfitting work.

Cable grouping is performed in the Production Department as a major part of production planning and given to the Design Department for completion of the last stage of detail design. The data base and processing system for cables, called CLIP (Cable List Program) is an important tool that is applied from functional design through production.

such as: cable lengths, cable-tray widths, penetration-piece requirements and material lists. From the outset, CLIP was developed and applied for the construction of sophisticated ships.

OVERALL ENGINEERING PROCEDURE

1) Design

- a. Functional Design - Major work typically includes generation of wiring diagrams, equipment arrangement, basic design data, and construction of a data base in CLIP.
- b. Detail Design - This stage specifically defines cable lengths, cable routings, cable trays, penetration pieces, etc. as well as the CLIP data base.



- 2) Production Planning - This is the most important phase because it converts the system-oriented information that was generated, during functional design into zone-oriented information. The work includes definition of cable-installation sequences and methods. The output of this phase is processed by CLIP to automatically produce required information such as material lists and cable-cutting instructions. Other work such as preparation of the manning plan, cable-installation scheduling, and setting pallet-delivery dates, are also performed during this phase.

Design and production planning are further described in the next parts of this paper.

DESIGN

In addition to the role CLIP plays as a tool for grouping work, it has remarkable merit for reducing required detail-design man-hours.

The development of an electric-wiring arrangement (EWA) accounts for a significant part of a detail-design effort. Before CLIP was introduced, an EWA was the only drawing developed for cable-installation work and pertinent purchasing-data generation. The preparation of EWA then required a high degree of skill; each cable was superimposed to 1/25 scale on hull structural drawings. The process was extremely time consuming and required a huge manpower investment. As an EWA shows all cable routes, it thereby indicates cable lengths, cable-tray dimensions, penetration-piece sizes, and comprises the basis for placing purchase orders. EWAS are also used for installing cables at the production site. CLIP succeeded, not only in simplifying EWA formats, but also, in substantially reducing man-hours and the time required for their preparation.

The design phase consists of:

- 1) Prerequisites - The following are required before starting data input into CLIP:
 - a. Wiring Diagrams - These are prepared per circuit. Ten-digit circuit numbers, the names of terminal equipments, and the types of cable to be used are identified.
 - b. Equipment Arrangement - The positions of electrical equipments in the context of a general arrangement, machinery arrangement, cabin arrangement, etc., are shown.
 - c. Main Cable-Way Guidance Plan - This is needed to determine locations for main-cable trays. As a general rule cable ways are superimposed on an equipment arrangement. This plan presents the distances from nearest hull structure to each cable way and also gives the positions and numbers of cable index points. The latter are used to determine routes, calculate cable lengths, establish cable-tray sizes, etc.
- 2) Data Input - CLIP requires the following data input during the design phase:
 - a. Cable-Standard Master - The outside diameters and unit weights for all types of cables to be used are required. Note should be made that much of these data are common to many ships. Therefore, much is retained in the master file that is common to other ships. The work required to input data for a specific ship is usually negligible.
 - b. Circuit Data - The circuit numbers, the names of terminal equipments and the zones they are located in, are inputted. Since these data are conserved from previous ships' files, the actual volume to be inputted for a specific project is reduced substantially.
 - c. Cable Route Data - The index numbers alongside the route of each circuit runs, and the distance from the terminal equipment to the nearest index point on the route, are inputted. Margins at both ends of each cable to be precut are taken into consideration at this time.
 - d. Cable-Way Data - The distances between all index points on the main cable way guidance plan are inputted. These data in combination with cable-route data used to calculate cable lengths.
- 3) Preliminary CLIP output - CLIP preliminarily outputs the following information after processing the data inputted during the design phase.
 - a. cable route list - The circuit number, the type of cable, the names of the terminal equipments, the index points through which the circuit pass, and the cable cutting length are outputted for every circuit in the form of a list.
 - b. Cable point list - By each index point, the circuit numbers of all cables pass through are outputted in the form of a list. The sum of outer diameters of all cables, that determines the cable tray width, is also provided.
 - c. Cable quantity - The required cable length is summed up for each cable type and the purchase order is forwarded to the cable supplier.
 - d. Fitting information - Sizes and required quantities of penetration pieces, "Multi Cable Transit"s (MCTS) and glands are outputted, and thereby the fabrication details are developed. Another computer system which is capable of on-line processing being connected to CLIP determines the arrangement of MCT elements in a frame.

Aforementioned outputs are next processed in a production planning phase for determining the best sequences and methods and for converting system-oriented information into zone-oriented information.

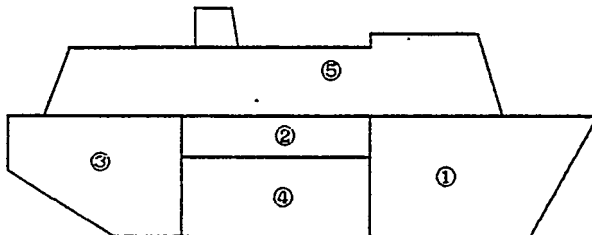
PRODUCTION PLANNING

Production planning work consists of the following processes:

- 1) Zone Designation - Figure 2 shows typical zone designations. In this example the ship is divided into five zones: forward, midships less the engine room, aft, engine room and superstructure. Each cable is assigned to the zone or zones through which it runs. Thus a cable may be assigned to one or as many as five zones. Cables in common zones are grouped by problems inherent in their installation. Then, they are broken down to the pallet (work package) level. A pallet is the smallest unit for the sake of controlling material and is determined in accordance with two levels of grouping;
- 2) First-Level Grouping - The cables assigned to each zone are first grouped, in accordance with factors, such as, time to be installed, cable way to share, and locations of terminal equipments. This grouping is also used to determine the fundamental work procedure which will have a significant impact on the success of subsequent planning and installation work. Therefore, the grouping is performed by the same production engineer who will be in charge of work for electrical outfitting on block and on board.

First level classifications are:

- a. Lighting-Cable Group - This work is given top priority because the ship's lighting fixtures will be used for illumination during construction. Since 80% of the cables in this group will be installed on upside-down blocks before hull erection, the work to be completed on board consists mostly of uncoiling cable ends and pulling them across erection joints.



- b. Interzone-Cable Group - These cables run across several zones. They are further broken down according to the zones where terminal equipments are located.
- c. Intercompartment-Cable Group - These cables run through several compartments within one zone.
- d. Local-Cable Group - These cables run exclusively inside a single compartment.
- e. Coiled-Cable Group - These are cables that are to be pulled into position except for their ends. The ends are temporarily coiled at a bulkhead or at a block erection joint pending being able to pull them into position during a latter work stage.
- f. Other-Cable Group - These are cables that do not fit into the aforementioned groups. Usually they are cables that cannot be installed until after certain equipments are blue-sky landed or after certain blocks are erected, e.g., a main engine and the engine-room closing block.

After such formal classification of cables, the most appropriate cable installation procedure is developed and documented as shown in Figure 3. Immediately thereafter, the production engineer who performed first-level grouping interact with engineers for other work in order to avoid unintentionally having troubles by doing different kinds of work in the same zone during the same stage. As a consequence of the interaction, all groups usually have to make some adjustments in their proposed schedules. An electrical master schedule is formulated simultaneously.

- 3) Second-Level Grouping - At this level, there is a further break down in order to generate pallets (work packages). Detail scheduling, setting pallet delivery dates, and identifying pallet-interface problems are part of second-level grouping responsibilities.

Second-level grouping is carried out by the supervisors who will be in charge of the actual cable-installation work. They are supervised by the engineer in charge of first-level grouping.

- ① FWD Zone
- ② Midship Zone Less Engine Room
- ③ AFT Zone
- ④ Engine Room Zone
- ⑤ Superstructure Zone

FIGURE 2 ZONE DESIGNATIONS

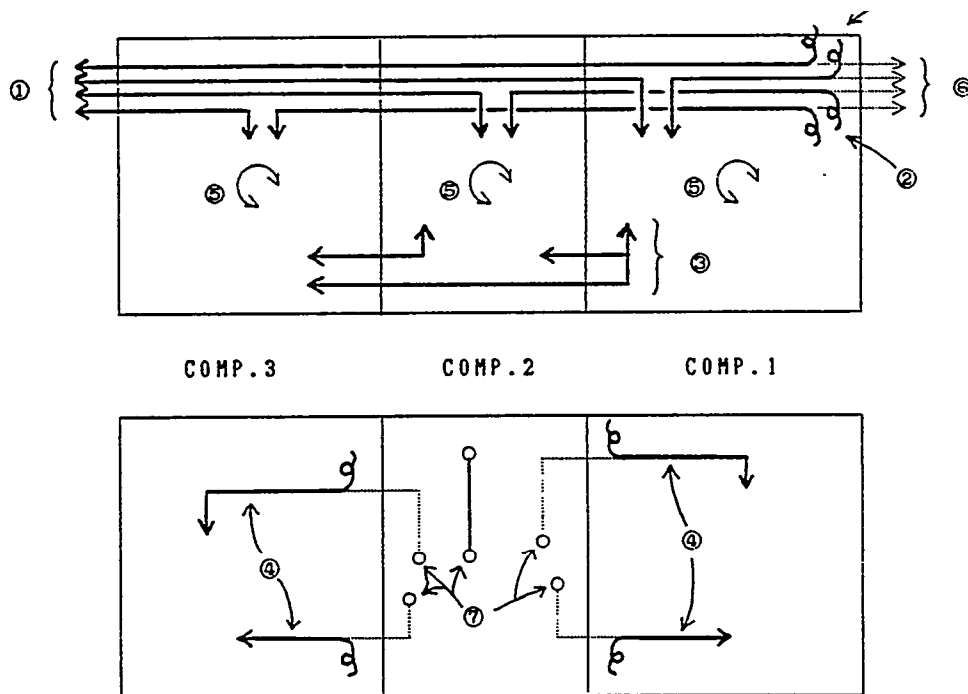
For each of the zones shown in Figure 2, an assistant foreman or a worker having sufficient experience and skill, would be in charge. As a matter of course, the foreman who coordinates electrical outfitting will give advice when need exists.

a. Second-Level Breakdown - Each first-level group is further broken down by taking into account such factors as terminal equipments, compartments in which equipments are located, cable trays shared, locations of penetration pieces, etc. As a consequence of this process the groups which are identified, each containing 30 to 40 cables, are regarded as pallets.

b. Implementation Schedule and Pallet-Delivery Dates - The electrical master schedule, formulated simultaneously with the cable installation procedure, is updated by making use of most recent planning information. Thereby, the

implementation schedule is formulated by breaking it down into activities which are the equivalents of pallets. Pallet-delivery dates are set based upon this latest activity.

c. Color Marking - Cables are positioned and strapped as soon as possible after they are pulled. Thus, despite extra length provided as a margin and correct precutting, a cable that is not pulled completely into its designed position could cause rework or even scrapping of the cable. The potential is greater when terminal points are located outside the working zone. In order to assist workers in pulling cables into their designed positions, the pre-cut cables are marked before they are pulled with colored vinyl tape at key points such as one which corresponds to a bulkhead penetration. Planning for such marking points is part of the second-level grouping activity.



- ① Engine Room Zone → APT Zone : Interzone Cable
- ② Engine Room Zone → FWD Zone : Coiled Cable
(Coiled at FWD BHD until FWD Zone is Ready)
- ③ Compartment 1 → 2,3 / 2 → 3 : Intercompartment Cable
- ④ Engine Room Zone → Superstructure Zone : Coiled Cable
via Closing Block
(Coiled at Erection Joint)
- ⑤ Local Cable within each Compartment : Local Cable
- ⑥ Uncoiling ② (To FWD Zone)
- ⑦ Uncoiling ④ (To Superstructure Zone)

- Engine Room Zone -
FIGURE 3 CABLE INSTALLATION PROCEDURE

- d. Interface Problems - At this level potential pallet-interface problems are identified in detail. They are organized as a check list to insure that they are addressed, solved and verified during the production phase. It goes without saying that this activity improves coordination efficiency and minimizes losses that would otherwise occur during construction.

The refined planning that results from second-level grouping is incorporated in CLIP.

- 4) Final CLIP Output - CLIP's refinement of preliminary planning yields the following:
 - a. Material List of Fittings (MLF) - Each MLF is a bill of material by pallet and represents a refinement achieved by some rearrangement of the CLIP-produced cable-route list during design phase. MLFs are used for production-control purposes, including by cable suppliers for precutting and assembling cable-lengths into pallets.
 - b. Cable-Point List - This is an updated version of the preliminary cable-point list.
 - c. Identification Stickers - These stickers are needed for the purpose of identifying precut cables during warehousing and installation. They are fried to both ends of each cable and identify circuit number, pallet number, names of terminal equipments, and color-marking specifications.

MLFs and identification stickers are delivered to cable suppliers. MLFs and the cable-point list are sent to production.

PRODUCTION METHODS

The following work methods which support zone-oriented cable installation are noteworthy:

- 1) Cable Precutting - Precutting virtually all cable is most important for implementing zone-oriented cable installation work. Each pallet consists of many types of cables that have common problems inherent in their installation. Systems to be served and cable types are not relevant. Therefore, bringing reels for many types of cable on board, as in traditional shipbuilding, is impractical and unsafe. They needlessly clutter working environments and, if not sufficiently secured, could be very dangerous on cambered decks or on decks that are inclined due to list, trim, etc.

All except very small-diameter cables, e.g., lighting-circuit cables, are precut. The supplier delivers precut cables pallet by pallet complete with identification stickers and color marking per MLF cutting and other instructions furnished by the shipyard.

- 2) Lighting Cable - In order to secure trafficability and workability on board, and sometimes even on block, a ship's lighting fixtures should be put into use as soon as a space is enclosed. The majority of lighting cable and fixtures are fitted on block when blocks are upside down, so that they can be lit immediately after block erection.

Usually, lighting cable pulled from reels comprises about 5% of total cable length required.

- 3) On-Block Outfitting - In addition to lighting cable end fixtures, cable trays, foundations and supports, penetration pieces associated with electrical systems, are also outfitted on block. This accounts for about 85% of required electrical fittings.
- 4) Bundled Wiring - Pulling several together, applies to cables that are relatively straight over long runs and that pass together through the same MCTs. If care is taken to avoid abrading cable insulation during the pulling process, manpower savings are realized by using small pneumatic winches and pulleys.

CABLE PROCUREMENT

Figure 4 shows a flow diagram for cable procurement processes. First, and initial purchase order is placed, based on preliminary quantity by cable type as produced by CLIP. Generally, the order is placed 90 or more days before the earliest pallet delivery date. A specific pallet delivery instruction, complete with MLF, cutting, identification and marking information, is issued 45 or more days before each required pallet-delivery date. For the purpose of assessing about when pallets should arrive, Figure 5 shows typical expected progress for cable installation work relative to key dates.

As a consequence of purchasing cable already precut, palletized and designated for just-in-time delivery by pallet, there is a great reduction in shipyard man-hours, space required for material handling, and in the total amount charged (interest) for the money used to purchase cable. Shipyard personnel are freed from reception and storage of hundreds of reels, precutting cables in warehouses or on board, and from other material marshaling chores.

Suppliers benefit also because demand on them does not fluctuate as much and their remuneration is greater because of the additional services they render. As long as they maintain sufficient supplies to assure shipyard deliveries on time, they have more freedom in serving other customers compared to having huge stocks in a shipyard warehouse, perhaps on consignment, that are not needed by the shipyard for quite some time.

Although supplier precutting, identifying and marking increases cable unit costs, the cost benefit from improved material and production control surpasses, by far, the cost increases. The result is unquestionably advantageous.

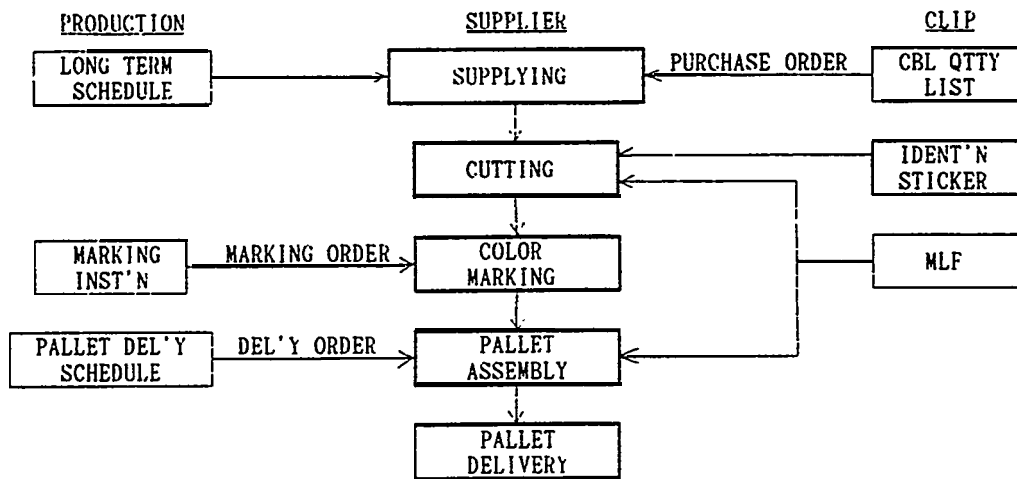


FIGURE 4 CABLE PROCUREMENT PROCESSES

Even if a cable supplier cannot be found to provide the increased services at reasonable added cost, precutting, identifying, marking and palletizing cable should be performed within a shipyard before cable is released to production. There is no question about it; there will be justifying savings resulting from improved production control through control of material.

EVALUATIONS

The various effects brought about in IHI shipyards by the approach described in this paper are:

- 1) There were substantial improvements in both design and production productivity. Accurate tracking of cable-pulling work progress was greatly facilitated. All that has to be done is "cross off" on cable-point and route lists as work progresses. As the work is classified by problem category per GT logic, productivity indicators such as man-hours per cable-length pulled, became very accurate and became sound bases for budgeting and scheduling for the normal performance of work, in a statistical sense. Thus, trends toward schedule lapses were immediately detected before they became of serious consequence. With prompt and appropriate remedial actions, unexpected delays were completely eliminated.
- 2) More efficient coordination was achieved between cable-pulling work and other types of work because interface problems were identified in advance. Such potential problems were discussed and priority countermeasures were incorporated during the planning and/or scheduling for all types of work involved.
- 3) The beneficial results of using group leaders to perform production planning, who were later to be in charge of cable installation work, were conspicuous during the production phase.

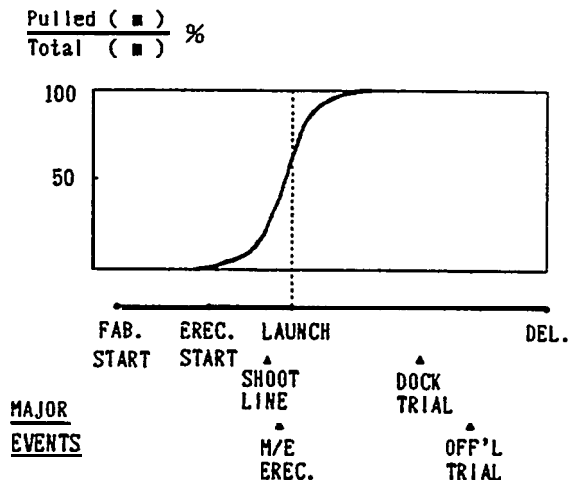


FIGURE 5 CABLE INSTALLATION PROGRESS

Besides what they contributed to planning documents, every small unwritten detail that they had detected while performing production planning, was recalled and applied by them, as they supervised cable installations, to manifestly further improve efficiency.

- 4) CLIP significantly streamlined design work. Noteworthy simplification was realized in the wiring arrangement which before, required many man-hours, skilled designers and large drafting tables. The skilled designers and saved man-hours are now applied for more sophisticated design duties. The CLIP processing system and data base are absolutely indispensable for transforming data by system to data by zone. The application of zone logic to facilitate cable installations is impractical without a processing system like CLIP and an appropriate data base. Moreover, CLIP made it practical to pre-cut cable because of its reliability when calculating cable lengths.

- 5) Since all cable information for a ship are conserved in the CLIP data base, design data so filed can be easily reapplied when building different ships of the same type. Moreover, because all significant aspects of cable usage are captured as corporate data that is readily recallable, cost estimating with a high degree of accuracy has become practical. In addition, the conserved data base has also proven to be very useful for modernizing, overhauling and repairing ships.

CONCLUSIONS

Cable installation work was once always regarded as the most difficult to plan and control with zone logic. But, after CLIP made it practical to transform system-oriented data to zone-oriented work packages, zone logic has been successfully applied and reapplied for installing cable in ships. The zone approach is now routine in IHI shipyards.

Improvement in coordination with other trades during the busiest stage of cable installation, is still being realized. The improvement process is not likely to stop.

Emphatically, the more complex that a ship is, the more CLIP is essential for cost, scheduling and quality matters. The fact that CLIP is applicable and effective for modernization, overhaul and repair work, in addition to construction work, is reiterated.

While cable installation work is generally held to be very important, its importance is increasing with the increasing density of cables required for the seemingly unlimited sophistication of numerous electric and electronic equipments of every kind, that are now being fitted in ships. CLIP is being improved to keep up with this extraordinary demand.

The addition of computer-aided design (CAD) functions for automatic design and drafting of fittings, and automatic determination of cable routes, are regarded as priority subjects to be dealt with in the future. But, at the same time, IHI is also applying priority efforts for the development of fiberoptic systems and multiplexed communication systems, for the purpose of reducing cable requirements.

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